# Carbon Analysis of Proposed Forest Management Regimes on the Elliott State Forest


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# EXECUTIVE SUMMARY

In 2010, the U.S. Fish and Wildlife Service (USFWS) contracted with Ecotrust to provide a carbon analysis of proposed management regimes in the Elliott State Forest. These included specific management restrictions outlined in a Habitat Conservation Plan (HCP) proposed by the Oregon Department of Forestry (ODF) to meet Endangered Species Act requirements and three different annual harvest volume targets. This is the first exercise of its kind to compare the carbon sequestration effects of management options on state managed forestlands.

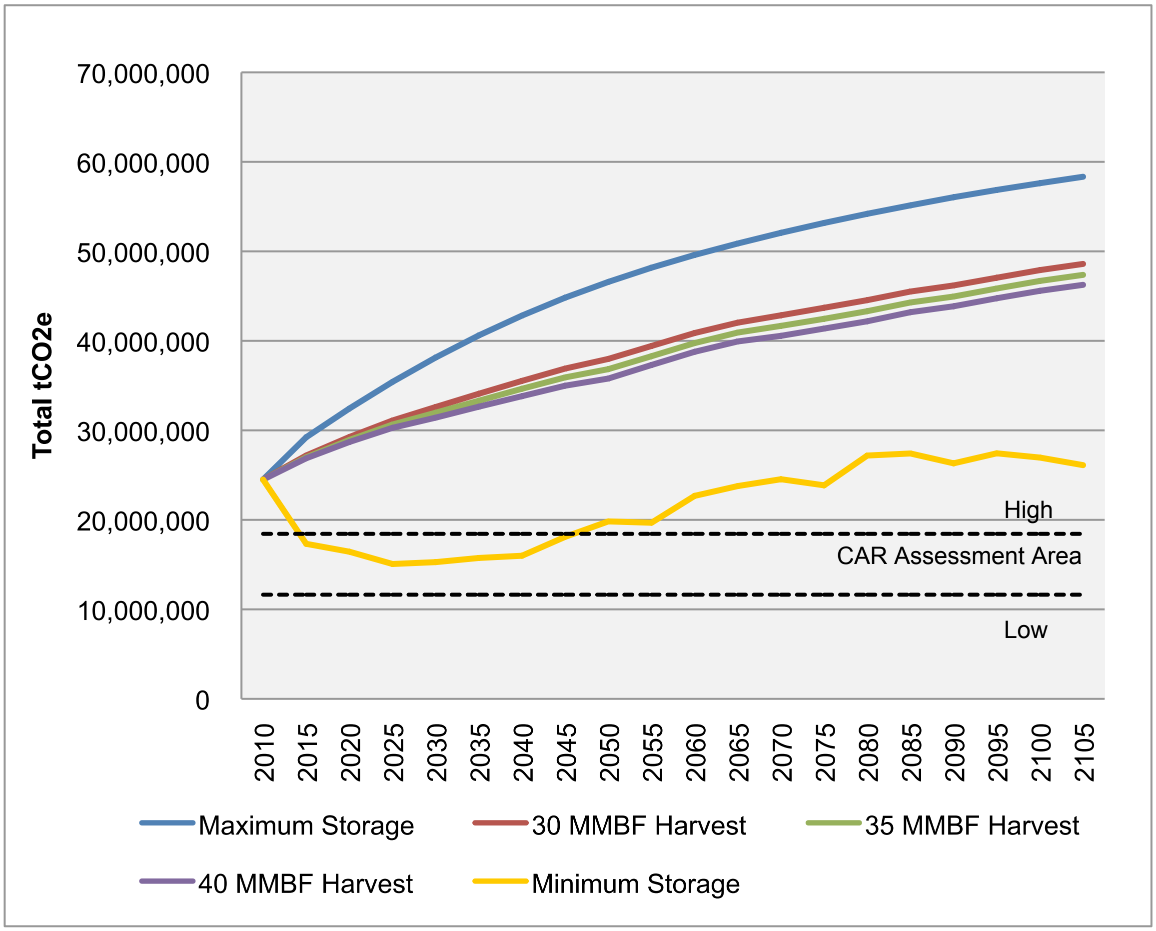
Working closely with USFWS and ODF staff, Ecotrust utilized the latest forest inventory data from the Elliott State Forest to model carbon sequestration potential of the proposed HCP-associated management prescriptions and three different annual harvest volumes: 30, 35, and 40 million board feet (MMBF). In addition, we evaluated three data sets for comparison: a maximum storage scenario, in which all Elliott lands are managed for maximum standing forest biomass; a minimum storage scenario, in which all Elliott lands are managed for timber production, while meeting the legal requirements of both the Oregon Forest Practices Act and the Endangered Species Act; and a regional average provided by U.S. Forest Service inventory data.

To develop these scenarios, we:

1. Selected a recognized and applicable third-party forest carbon offset protocol;
2. Adapted the protocol to evaluate management proposals for the Elliott State Forest;
3. Defined carbon pools to be included in the analysis;
4. Modeled carbon storage over time, following management prescriptions and optimizing harvest schedules; and
5. Calculated carbon storage on the forest, while accounting for storage in wood products.

Our modeling outputs provide a long-term look, in five-year increments, at scenarios for forest growth, timber yield, and carbon storage under varying management plans. Results are summarized in Figure 1.

**Figure 1: Carbon Storage Potential**

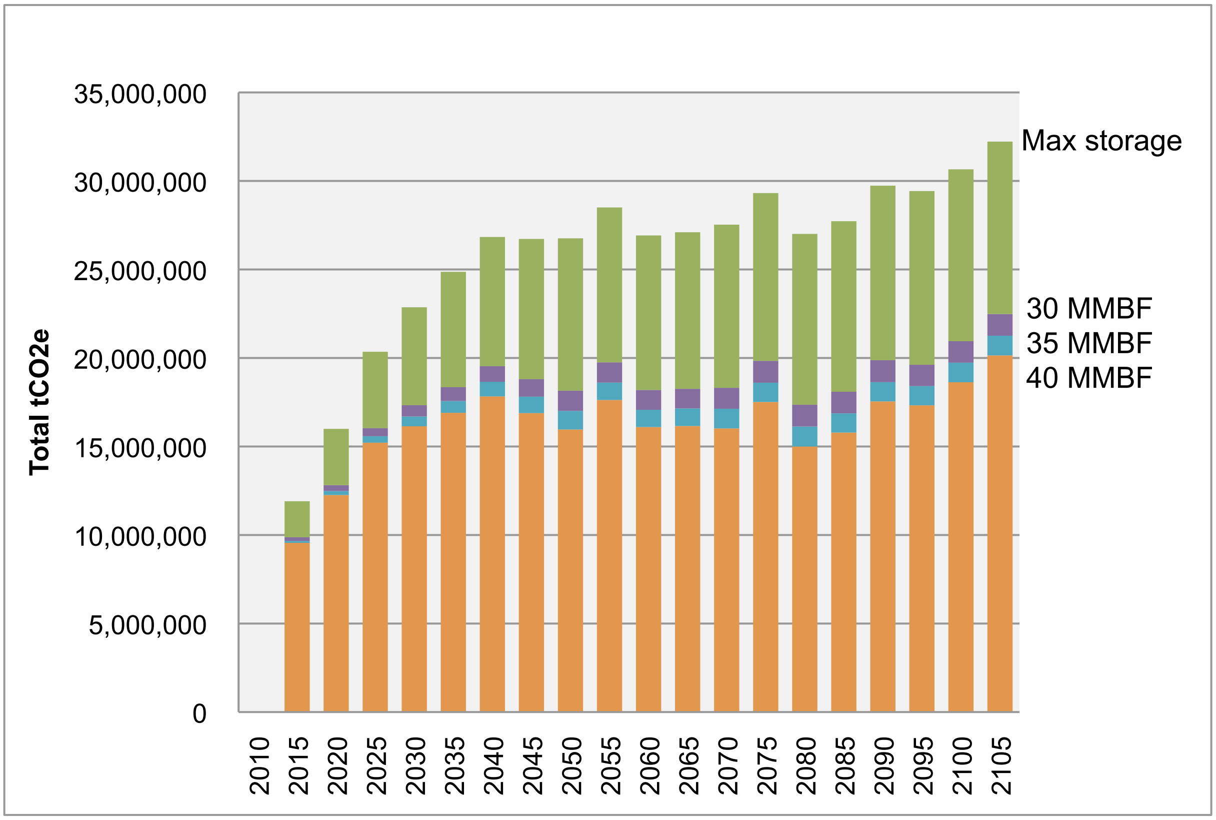



Cumulative differences described in Figure 1 are striking for what they say about the potential of Pacific Northwest forests to store carbon. If no harvests were to occur in the Elliott State Forest, the total amount of carbon stored would be approximately 46.6 million metric tonnes of carbon dioxide equivalent (MMtCO2e) by 2050, an amount that is equivalent to approximately 68.5 percent of the annual emissions of greenhouse gases for the entire state in 2007 (68 MMtCO2e).[1] As these results indicate, forest management has the potential to contribute significantly to Oregon's greenhouse gas emissions reductions.

The potential differences that alternative management could achieve are demonstrated in Figure 2. This set of graphs shows how much carbon would be stored by four management alternatives (no harvest, 30 MMBF, 35 MMBF, 40 MMBF) compared with what would be allowed on the site if it was in private hands. The difference in carbon storage between the maximum and minimum values is approximately 20 million metric tonnes of carbon dioxide equivalent (MMtCO2e) in 2025. This number increases to a total of approximately 27 MMtCO2e additional metric tonnes by 2050. To put this amount in context, 27 MMtCO2e represents approximately 40 percent of the total greenhouse gas emissions for the state of Oregon in 2007 (68 MMtCO2e).

[1] Revision and Update to the Oregon Greenhouse Gas Inventory. Oregon Department of Energy (http://www.oregon.gov/ENERGY/GBLWRM/Oregon_Gross_GhG_Inventory_1990-2007.htm)

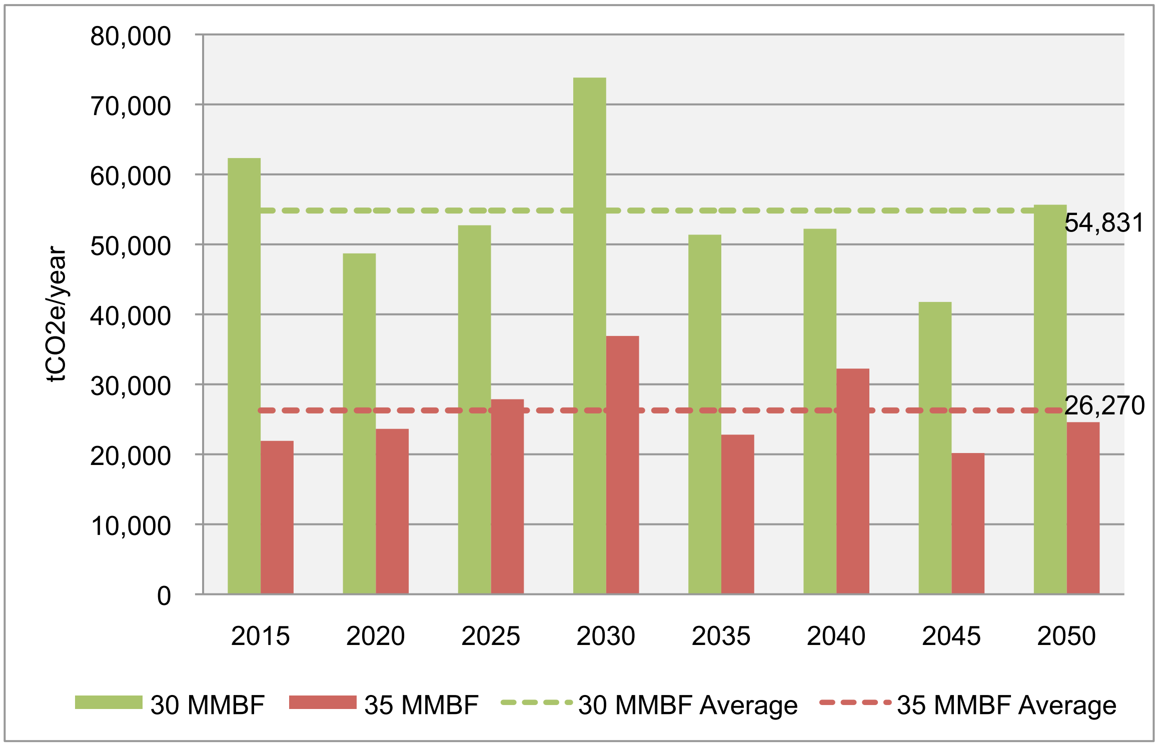
**Figure 2: Cumulative Carbon Storage Above Minimum**




The HCP-based management scenarios we modeled in this report fall somewhere between the maximum and minimum storage possible on the site. In percentage terms, the different harvest level scenarios would store between 60 and 68 percent of the maximum possible on the site by 2050.

Figure 3 shows annual differences between the three proposed harvest levels and the HCP restrictions. In this example, we take the highest harvest level as a baseline and compare the other harvest levels against it. If we average the annual differences over the next 40 years, switching management from the 40 MMBF harvest scenario to the 30 MMBF will save an amount equal to the annual carbon emissions of about 10,000 cars traveling on U.S. highways each year.[2]

**Figure 3: Annual average reductions with different harvest scenarios**




[2] Emission Facts: Greenhouse Gas Emissions from a Typical Passenger Vehicle. Environmental Protection Agency.. (http://www.epa.gov/oms/climate/420f05004.htm)

# 1. Introduction

The Intergovernmental Panel on Climate Change (IPCC) recognizes forestry practices as important to the mitigation of greenhouse gas emissions. Among currently available mitigation opportunities, the IPCC lists afforestation, reforestation, forest management, reduced deforestation, and harvested wood product management.[3] In addition, the IPCC notes that "substantial co-benefits" can be achieved through forest-related mitigation activities, including employment, biodiversity, and watershed conservation.[4]

In Oregon, the governor's office has urged that "the consideration of climate change [be] a key element in our current planning and decision-making processes,"[5] and the Oregon Global Warming Commission has established 2020 and 2050 targets for reduction of greenhouse gases.[6] A top priority in meeting the targets, as described by the Commission's Forestry Working Group in September 2010, is the development of carbon inventories for the state's public and private forests.[7]

New management proposals for the Elliott State Forest provide an opportunity to develop a context-specific analysis of the mitigation benefits of forest management. In July 2010, the U.S. Fish and Wildlife Service (USFWS) contracted with Ecotrust to provide estimates of potential carbon sequestration volumes. These estimates are based on a combination of annual harvest target levels and specific requirements of the Habitat Conservation Plan (HCP) developed by the Oregon Department of Forestry to meet the requirements of the Endangered Species Act in providing habitat for Pacific salmon and steelhead, northern spotted owls, marbled murrelets, and other species dependent on older forest characteristics.

Working closely with USFWS and ODF staff, Ecotrust utilized the latest forest inventory data for the Elliott State Forest in southern Oregon to model its carbon sequestration potential according to proposed management scenarios. For additional context, we examined two other management scenarios that we expect will provide minimum and maximum carbon storage on the site. The last point of reference we are providing is a regional average for the area surrounding the Elliott State Forest based on U.S. Forest Service long-term inventory data.

## 1.1 Project Site Description

The Elliott State Forest covers 93,282 acres of Oregon's coastal forest south of the Umpqua River. It is located in Douglas and Coos Counties and extends from within six miles of the ocean to the crest of the coast range (Figure 4). The lands of the Elliott State Forest were assembled over the past 85 years through a series of land trades and acquisitions. When Oregon was granted

[3] IPCC, 2007: Summary for Policymakers. In: Climate Change 2007: Mitigation. Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [B. Metz, O.R. Davidson, P.R. Bosch, R. Dave, L.A. Meyer (eds)], Cambridge University Press, Cambridge, UK and New York, USA.

[4] IPCC, 2007: Summary for Policymakers. In: Climate Change 2007: Mitigation. Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [B. Metz, O.R. Davidson, P.R. Bosch, R. Dave, L.A. Meyer (eds)], Cambridge University Press, Cambridge, UK and New York, USA.

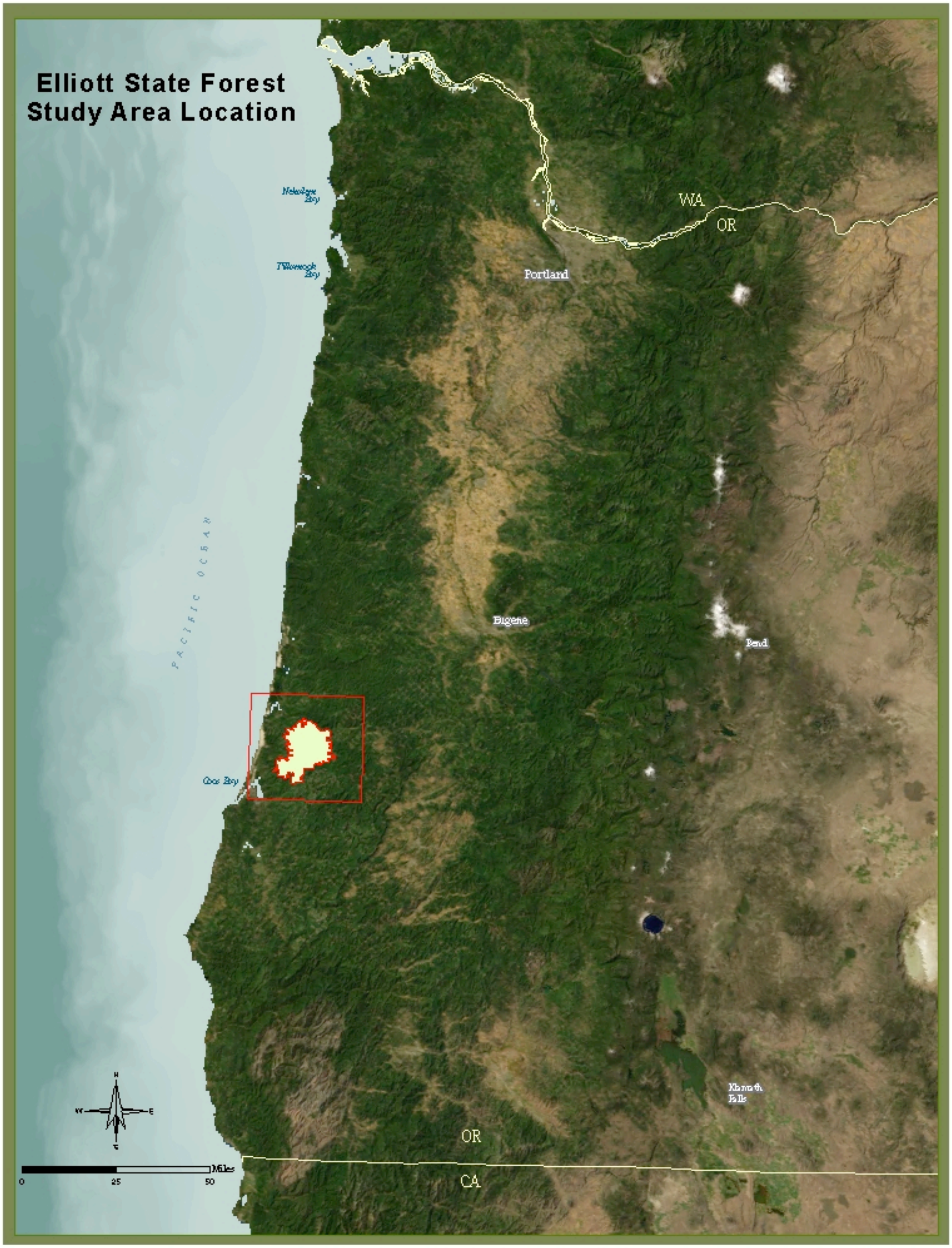
[5] Governor's Climate Change Integration Group. 2008. Final Report to the Governor: A Framework for Addressing Rapid Climate Change.

[6] Governor's Advisory Group for Global Warming. 2004. Oregon Strategy for Greenhouse Gas Reductions, p. 9

[7] Oregon Global Warming Commission. 2010. Interim Roadmap to 2020.

statehood, two sections within every township were given to the state. In order to generate revenue, the state sold most of this land and a large portion of the remainder was left scattered inside the newly established national forests. In order to consolidate these lands into a single contiguous block, the state forester and governor traded this patchwork of lands for the single tract that became the Elliott State Forest.

**Figure 4: Location Map**



The Elliott State Forest is comprised of a mix of native species, with a predominance of conifers such as Douglas fir, western hemlock, and Sitka spruce. Age classes reflect management categories, with approximately half the acreage managed as even-aged stands on shorter rotations, and the other half managed for older-stand structure. The results of these two management approaches can be seen in the bimodal distribution of age classes across the Elliott, as demonstrated in Figures 5 and 6.

**Figure 5: Elliott State Forest Age Class Distribution (2008)**

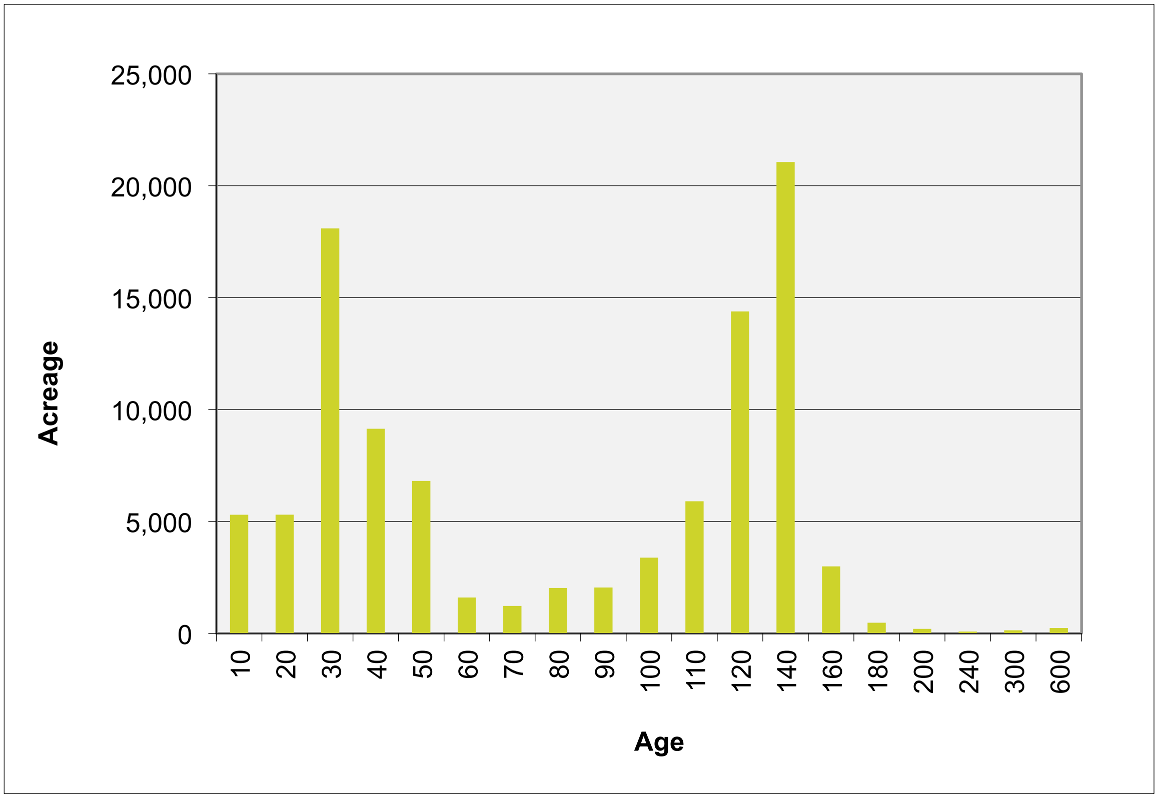
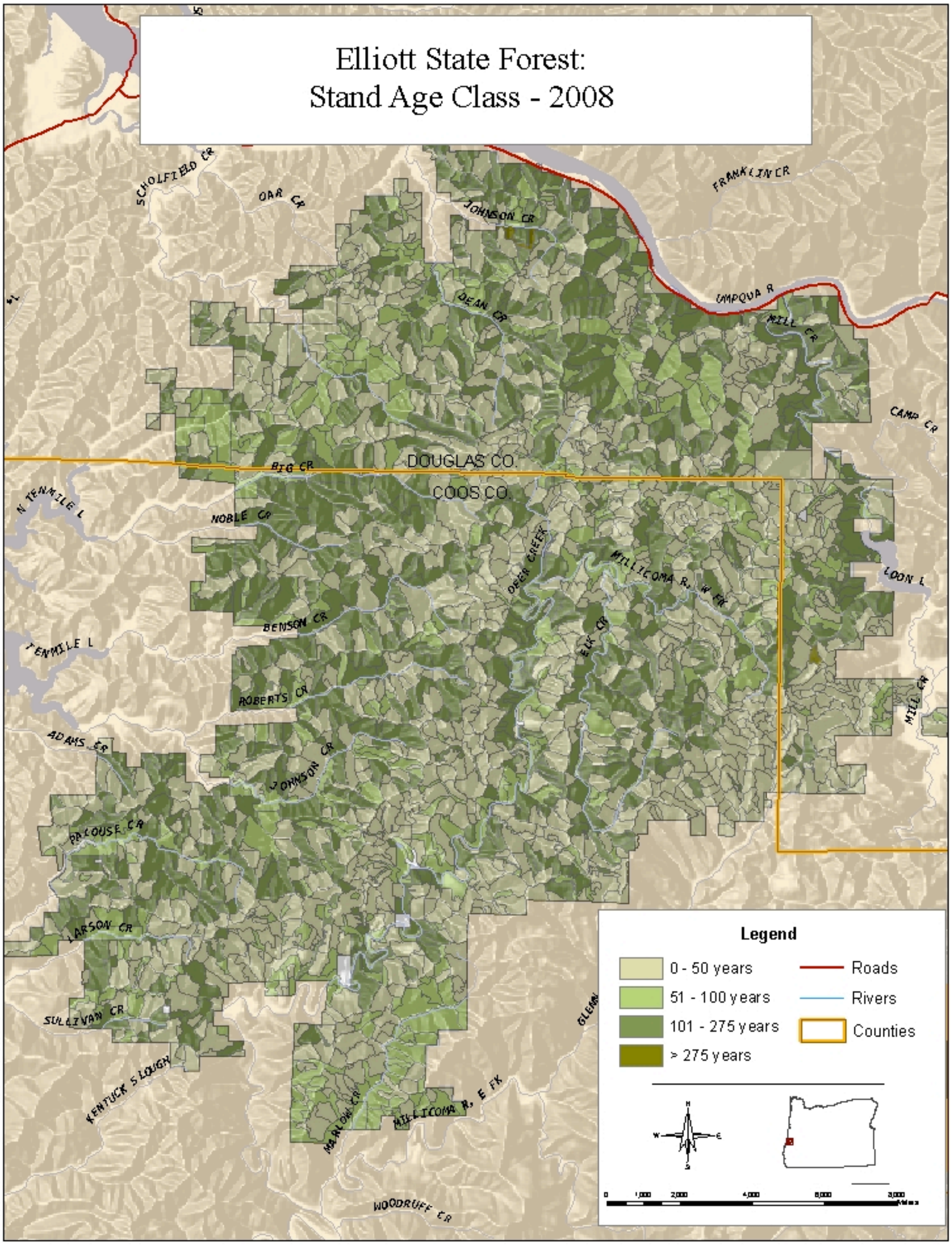


**Figure 6: Elliott State Forest Age Class Map**



The Elliott lands are divided into two major categories based on where funds from harvests are budgeted. The original consolidated block of lands assembled by the 1930s was consolidated into the Common School Forest Lands (CSFLs). In 1940, more lands were added to the Elliott State Forest when local counties deeded thousands of acres of tax-delinquent forestland next to the Elliott to the state to be managed for the benefit of the local counties.[8] These added tracts became Board of Forestry Lands (BOFLs).

## 1.2 Elliott State Forest Management

Despite the two distinct categories of land in the Elliott State Forest, it is managed as a single unit. Of the total 93,282 acres in the Elliott, the Common School Forest Lands (CSFLs) cover 84,562 acres (91%)[9] and are owned by the state of Oregon, which, acting through its State Land Board, arranges for management through the Oregon Department of Forestry to provide income to the Common School Fund. ODF manages a total of 123,225 acres of CSFL throughout the state, a majority of which are in the Elliott.[10] The remainder of the Elliott acreage is BOFLs, totaling 9,088 acres.[11]

Management goals for the Elliott State Forest are stated in ODF planning documents as:

1) *Actively manage CSFLs with the objective of obtaining the greatest benefit for the people of this state, consistent with the conservation of this resource under sound techniques of land management to maximize revenue for the CSF over the long term*
2) *Actively manage BOFLs to secure the greatest permanent value to the citizens of the state of Oregon by providing healthy, productive, and sustainable ecosystems that, over time and across the landscape, provide a full range of social, economic, and environmental benefits to the people of Oregon*
3) *Meet the requirements of the federal and state Endangered Species Acts (ESAs) through an approved Habitat Conservation Plan (HCP), using a forest ecosystem management and multi-species approach*
4) *Ensure that the Elliott State Forest contributes to habitats needed by the listed and unlisted species, and fish populations covered by this HCP*
5) *Promote the development, maintenance, and enhancement of wildlife habitats through active management approaches that use a variety of silvicultural techniques*
6) *Provide for short-term certainty and long-term stability in the management of state forests to meet legal mandates*[12]

After the 1992 listing of the northern spotted owl as a threatened species, the Department of State Lands and its board requested that ODF work closely with the Oregon Department of Fish

[8] Oregon Department of Forestry. 2006. Elliott State Forest Management Plan, pp. 1-5

[9] Oregon Department of Forestry. 2009. 2009-2011 Backgrounder on the Elliott State Forest.

[10] Oregon Department of Forestry. 2008. Common School Forest Lands Annual Report FY2008.

[11] Oregon Department of Forestry. 2006. Elliott State Forest Management Plan.

[12] Oregon Department of Forestry. 2008. Draft Elliott State Forest Habitat Conservation Plan. This includes requirements of the Endangered Species Act on the site.

and Wildlife to develop a comprehensive plan that would address all aspects of the forest ecosystem. This led to the creation of the 1995 Forest Management Plan, which remains the primary management document for the Elliott State Forest.

In 1995, USFWS approved a 60-year incidental take permit for the northern spotted owl and a six-year incidental take permit for the marbled murrelet. In 2000, with the impending expiration of the marbled murrelet permit, ODF began planning for a new HCP to address potential impacts to both threatened species.

ODF developed potential management prescriptions that would maintain structural elements of the forest that would provide habitat for murrelets, owls, and salmonid species. These included defined actions that could be taken on individual forest stands, in riparian buffer zones, and in protected areas surrounding nesting sites. In addition to defining actions that could be taken on a specific local area, the HCP defined structural targets to be maintained across the entire Elliott.

Along with the HCP management prescriptions, we modeled three different annual harvest targets. The ODF determined that the overall structural targets required for the HCP could be achieved at each of the three harvest levels. This range of harvests is currently being reviewed by the two agencies largely responsible for approving the HCP, USFWS, and NOAA Fisheries. After considering the overall forest structure and habitat value that can be achieved under each harvest scenario, these agencies will determine whether they will issue a new incidental take permit.

The three proposed HCP harvest levels are:

1) 30 million board feet/year
2) 35 million board feet/year
3) 40 million board feet/year

## 1.3 Historical Harvest Levels in the Coos District

Historical annual harvest levels in the Coos District, where the Elliott State Forest is located, place these proposed HCP harvest levels in context. Table 1 describes harvest levels since 1995, the year Elliott State Forest Management Plan was implemented to protect wildlife species in the Elliott. Because the Elliott is also managed to "maximize revenue for the CSF over the long term," we include in Table 1 historical data on harvest values and stumpage prices.

**Table 1: Coos District Harvests and Revenue**

| Fiscal Harvest Volume and Value<br>Coos District (Coos & Douglas Counties) | | | | |
|---|---|---|---|---|
| **Fiscal Year** | **Net MMBF** | **Gross $M** | **Average Stumpage** | **Sales** |
| 1995 | 11.5 | $7.38 | $758 | 7 |
| 1996 | 14.3 | $11.99 | $645 | 9 |
| 1997 | 21.0 | $14.57 | $556 | 12 |
| 1998 | 21.2 | $13.15 | $515 | 11 |
| 1999 | 32.0 | $17.66 | $469 | 15 |

| | | | | |
|---|---|---|---|---|
| 2000 | 41.6 | $20.89 | $500 | 13 |
| 2001 | 33.9 | $17.79 | $435 | 9 |
| 2002 | 27.6 | $13.77 | $356 | 10 |
| 2003 | 18.8 | $8.77 | $431 | 8 |
| 2004 | 28.9 | $13.28 | $435 | 13 |
| 2005 | 33.3 | $18.24 | $536 | 9 |
| 2006 | 12.8 | $6.81 | $550 | 8 |
| 2007 | 23.4 | $12.18 | $449 | 5 |
| 2008 | 19.9 | $11.35 | $439 | 9 |
| 2009 | 21.1 | $9.31 | $278 | 4 |
| 2010 | 17.8 | $6.91 | $340 | 10 |

Note that there are complications in the way these data have historically been reported. Table 1 references data from the Coos District CSFLs in Coos and Douglas Counties as compiled by the Oregon Department of Forestry. These data include the 84,562 acres of CSFL in the Elliott, as well as 4,968 acres of CSFL elsewhere in the district, but do not include the 9,088 acres of BOFL in the Elliott.

Total harvests, timber value and stumpage prices are demonstrated in Figures 7, 8, and 9. Stumpage values for any given year reflect an average bid price for each sale weighted by appraised species volume.

**Figure 7: Coos District Total Harvests (Million Board Feet)**

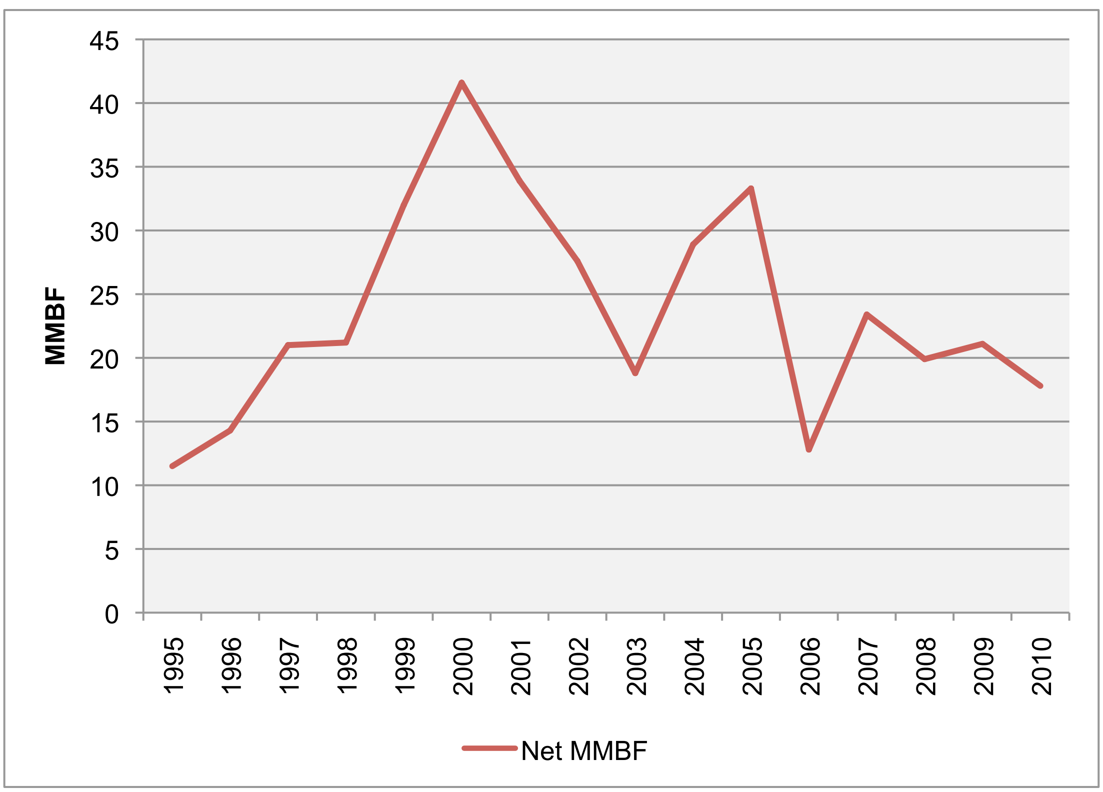


**Figure 8: Coos District Harvested Timber Value ($Million)**

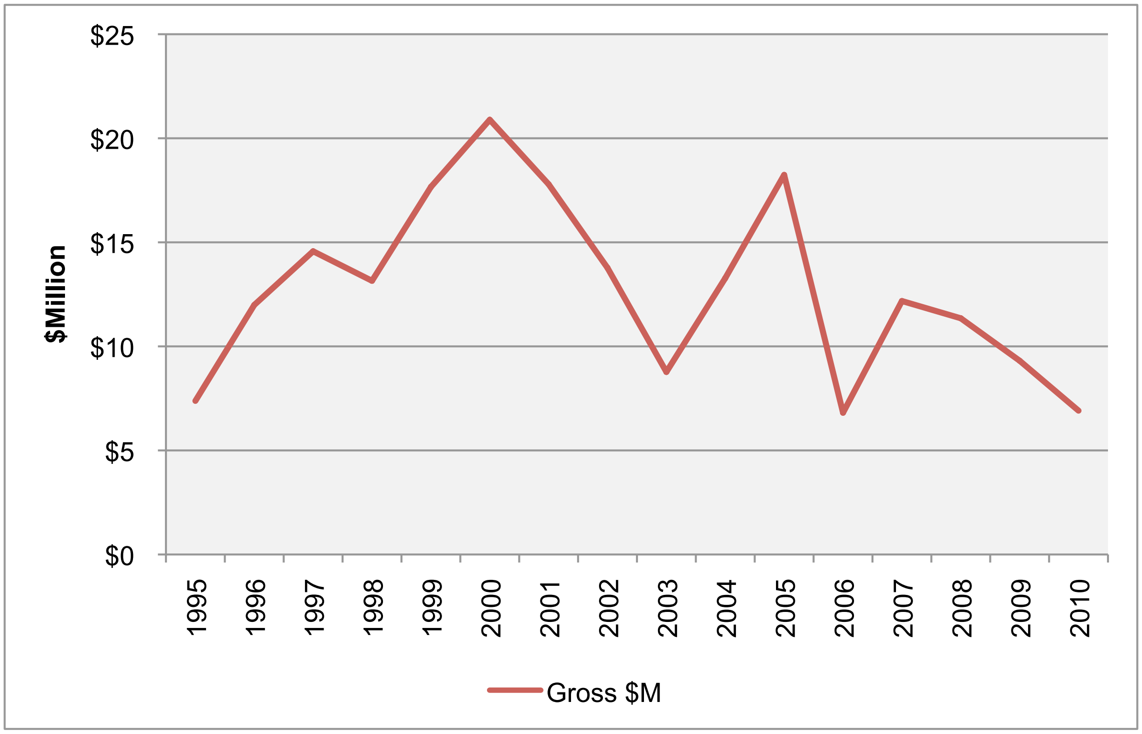
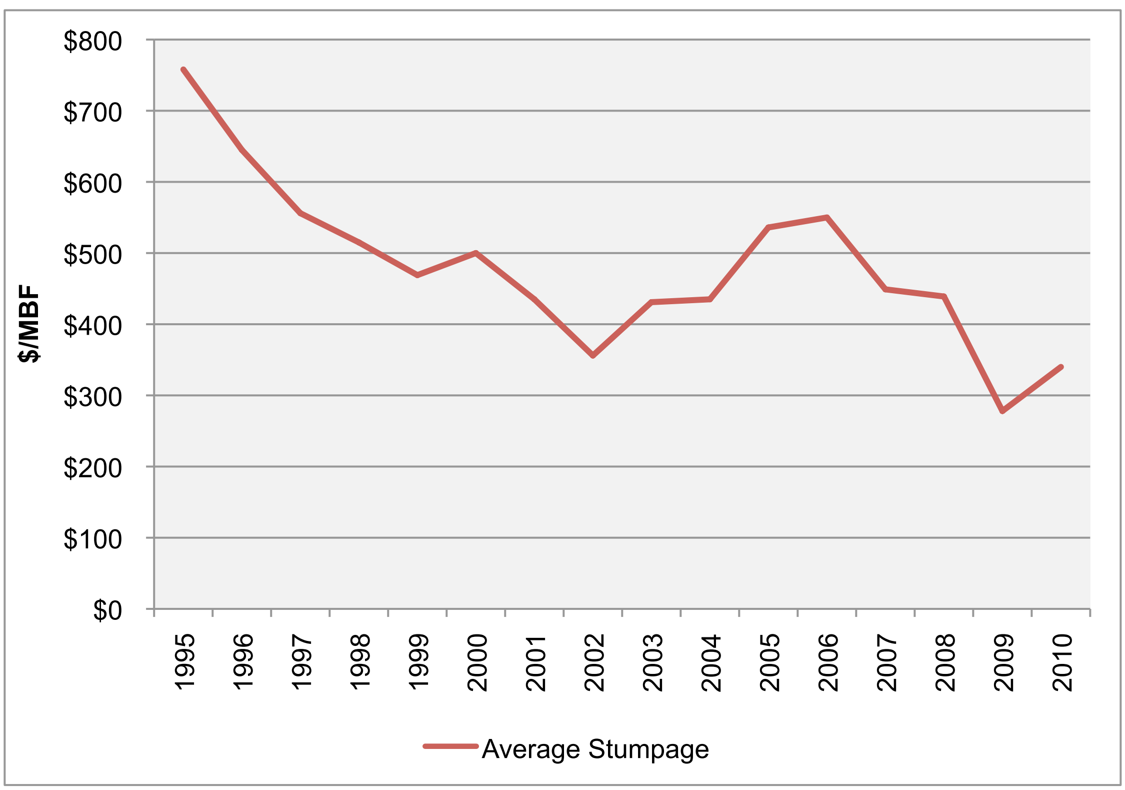



**Figure 9: Average Bid for Thousand Board Feet Weighted by Species**



## 1.4 Oregon State Commitments for Greenhouse Gas Reductions

Oregon was one of the first states to commit to reducing greenhouse gas emissions. In 2003, the governors of California, Oregon, and Washington launched the West Coast Governors Global Warming Initiative as a regional response to climate change.

In February 2004, Oregon Governor Ted Kulongoski appointed the Governor's Advisory Group on Global Warming to draft a statewide climate plan that would promote long-term environmental sustainability, protect public health, promote social equity, create economic opportunity, and expand public awareness.[13] One result of this group's efforts was the 2004 "Oregon Strategy for Greenhouse Gas Reductions," which established the following statewide goals:

1) *By 2010, arrest the growth of Oregon's greenhouse gas emissions (including, but not limited to $CO_2$) and begin to reduce them, making measurable progress toward meeting the existing benchmark for $CO_2$ of not exceeding 1990 levels.*
2) *By 2020, achieve a 10 percent reduction below 1990 greenhouse gas levels*
3) *By 2050, achieve a "climate stabilization" emissions level at least 75 percent below 1990 levels.* [14]

Total state emissions in 1990 were 58.7 million metric tonnes of carbon dioxide equivalent (MMtCO2e) and are projected to rise to 94.5 MMtCO2e annually by 2025 under a "business as usual" scenario. The Governor's Advisory Group recommended actions for greenhouse gas mitigation across five sectoral areas: energy efficiency; electric generation and supply; transportation; materials use, recovery, and disposal; and biological sequestration. Priority actions in these five areas were estimated to be able to reduce annual emissions to a total of 62.8 MMtCO2e by 2025, 7% higher than in 1990 and falling short of the overall goal, but placing emissions on a trend consistent with it.

The report reviewed a small group of management actions in the state's forest lands that could be adopted to help the state meet its goals for greenhouse gas reductions. Three major actions were considered: wildfire risk reduction, reduced deforestation and soil degradation (from land use planning), and afforestation of unproductive lands capable of growing forests. These three areas were estimated to contribute 3.2, 0.6, and 0.5 MMtCO2e to annual emissions reductions, respectively. We conclude that, of the 31.7 MMtCO2e in priority reductions, relatively easy to achieve biological sequestration reductions are expected to deliver 13.6 percent.[15] What was not included in this analysis was the impact of large-scale changes in forest management on federal or state lands. If these actions were considered, there would be a much larger estimate of potential reductions that could be achieved within the forestry sector.

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[13] Governor's Advisory Group for Global Warming. 2004. Oregon Strategy for Greenhouse Gas Reductions, Appendix E, p. E-1.

[14] Governor's Advisory Group for Global Warming. 2004. Oregon Strategy for Greenhouse Gas Reductions, p. ii.

[15] The graph of sectoral area contributions to the 2025 target on page 47 of the report does not include a corresponding data table. We obtain the figure of 13.6 percent by comparing total emissions reductions in the biological sequestration sector with those in all sectors. Note that the three biological sequestration actions (wildfire risk reduction, reduced deforestation and soil degradation, and afforestation) are not mutually exclusive and were described in the report as not additive.

Building on the work of the Governor's Advisory Group, the Oregon State House of Representatives passed bill 3543, which established the Oregon Global Warming Commission, an advisory body responsible for defining a pathway for achieving these 2010, 2020, and 2050 statewide goals. Since July 2010, the Global Warming Commission has convened a series of working groups to create a more detailed road map for achieving the targeted reductions outlined in House Bill 3543. This work is organized around six major sectors of opportunity: transportation, energy, industry, agriculture, materials, and forestry.

Results of this work have been published in the Oregon Global Warming Commission's "Interim Roadmap to 2020." The recommendations for the forestry sector include the following points of relevance to the management of state forest lands and to the Elliott State Forest choices being considered in this report:

**Carbon Inventory**

- Establish a carbon inventory for all Oregon forests. This will require a collaborative effort to define and develop an agreed-upon approach for developing and maintaining a carbon inventory system. Based on these data, establish baselines and both long-term and intermediate goals for carbon storage that account for different forest types and ownerships, including overall storage gains in public forests.[16]

**Public Forests — Existing State Forestlands Management**

- All timber management planning and public forest transactions (e.g., timber sales, offset sales) should include net impact on Oregon's carbon account.[17]

- Oregon State forestlands should be managed to increase carbon stores over time, consistent with ecosystem values and yield of durable forest product.[18]

[16] Oregon Global Warming Commission. 2010. Interim Roadmap to 2020, p. 115.

[17] Oregon Global Warming Commission. 2010. Interim Roadmap to 2020, p. 116.

[18] Oregon Global Warming Commission. 2010. Interim Roadmap to 2020, p. 117.

# 2. Methods

Modeling carbon stocks and potential sequestration rates requires a carbon accounting system that offers clearly defined and widely accepted guidelines. In our accounting system for the Elliott State Forest, we:

1. Selected a recognized and applicable third-party protocol;
2. Adapted the protocol to evaluate management in the Elliott State Forest;
3. Defined carbon pools to be included in the analysis;
4. Modeled carbon storage over time, following management prescriptions and optimizing harvest schedules; and
5. Calculated carbon storage in the Elliott, while accounting for storage in wood products.

## 2.1 Selecting a Protocol

Since spring 2009, Ecotrust has worked with private landowners to develop projects for the voluntary carbon market. As a part of this process, we reviewed several of the major forest carbon offset protocols created for use in the United States and around the world. We included the Climate Action Reserve, American Carbon Registry, and Voluntary Carbon Standard in our research efforts. After review, we determined that the Climate Action Reserve has created some of the most rigorous and thoroughly vetted methods that would be appropriate to measuring the potential carbon storage of the site and the outlined management proposals for the Elliott State Forest.

In October 2009, the Climate Action Reserve (CAR) released Forest Project Protocol version 3.1, created with the input of forest industry experts, non-profit organizations, forest consultants, and forest management agencies. As a result of this broad public comment process, the protocol has gained wide acceptance and, as of October 2010, it lists 24 Improved Forest Management projects under development in the United States.[19] The CAR methodology was developed to assure that carbon offsets developed for trading in the private market meet high standards for accuracy, additionality, and permanence.

Under CAR, project developers can create offset projects across the United States under a variety of forest management scenarios. For each project type, the protocol defines eligibility requirements, commitments for permanence and additionality, and methods for calculating carbon pools. Management activities that are recognized by CAR include reforestation, avoided conversion, and improved forest management.

## 2.2 Adapting CAR Methods for use in the Elliott State Forest

Decisions to be made about proposed Elliott State Forest HCPs reflect changes in forest management, rather than reforestation or avoided conversion; therefore, the CAR improved forest management protocol best suits the activities that are taking place in the Elliott State Forest. In a market context, the CAR improved forest management protocol requires that regional forest data developed by the U.S. Forest Service be used to establish a baseline, or

[19] Climate Action Reserve projects listed at the APX registry (https://thereserve1.apx.com/myModule/rpt/myrpt.asp)

"common practice" performance standard, against which the project will be compared. For public lands, this baseline also takes into account historical trends and likely future policy developments.

Since we were not evaluating the management impacts in the Elliott State Forest for their potential to deliver carbon credits, we did not follow the protocol requirements for determining baseline. Instead, we used the protocol to define the carbon pools that would be measured under each scenario.

We considered several approaches for shedding additional light on the carbon storage potential of the HCPs proposed for the Elliott State Forest. First, as requested by ODF and USFWS, we calculated the carbon sequestration rates of the three proposed HCP plans. Then we examined their differences, in effect, taking the 40 million board feet (MMBF)/year HCP as the baseline and assessing the additional storage offered by harvest levels of 35 or 30 MMBF/year.

In order to better understand the range of potential choices surrounding these proposed HCP management scenarios, we also compared them against two boundary scenarios: a maximum storage scenario, in which all Elliott lands are managed for maximum standing forest biomass, and a minimum storage scenario, in which all Elliott lands are managed according to what would be allowed on private lands following the Oregon Forest Practices Act and the Endangered Species Act.

Thus, we examined five scenarios:

- 30 MMBF
- 35 MMBF
- 40 MMBF
- Maximum Storage (i.e., boundary scenario of "no harvest")
- Minimum Storage (i.e., boundary scenario of "private forest allowable harvest")

To provide a wider regional context, we chose to compare the carbon sequestration potential of the Elliott State Forest with forests in the larger region. Therefore, we have included a range of values that demonstrates the high and low values for carbon storage across the entire Elliott State Forest (excluding the impact of harvested wood products) by using the regional carbon numbers provided by the Climate Action Reserve for the local region where the Elliott State Forest lies. These numbers are provided in units of tCO2e per acre stored in above-ground biomass for each defined assessment area. These values have been developed by CAR from U.S. Forest Service Forest Inventory Analysis data for each mapped supersection across the continental United States.[20] Within each supersection are assessment areas that are defined by a combination of geographic location and species mix. The Elliott State Forest lies within the "Oregon and Washington Coast – Northwest Coast Range Forest" assessment area.

In addition to species and geography, the amount of above-ground carbon stored in the Elliott on a per-acre basis is determined by the specific site classes found across the land to be evaluated. We chose to present the high and low per-acre values calculated across the total acreage of the

[20] Climate Action Reserve. 2009. Appendix F, Maps for the region of the Elliott State Forest available at (http://www.climateactionreserve.org/wp-content/uploads/2009/03/Supersections-Northwest.pdf)

Elliott State Forest based on the high and low values provided by CAR to calculate regional carbon stores.

In order to make this calculation, we first converted the above-ground carbon-per-acre value to an above- and below-ground value. We completed this by calculating the ratio of above-ground carbon to above- and below-ground carbon outputs generated by our FVS modeling over the 100-year modeling scenario across the Elliott State Forest. This provided a ratio of above-ground carbon as approximately 1.4 times the below-ground carbon volume. Applying this ratio to the per-acre value and then multiplying by the total acreage of the Elliott provided us with a high and low regional average above and below ground.

## 2.3 Defining Carbon Pools

The CAR improved forest management methodology defines major carbon pools to be measured and modeled. The most significant ones are above- and below-ground carbon volumes in live and dead standing trees. CAR also provides methods and equations to account for the storage of carbon in harvested wood products, since this carbon is not immediately released to the atmosphere. Carbon pools defined by CAR but not considered in our analysis, due to the difficulty of accurate modeling with current software, included downed woody debris, understory vegetation, organic litter, and soil carbon.

Thus, in this analysis, we evaluated the following carbon pools: standing live carbon, standing dead carbon, forest product carbon in use, and forest product carbon in landfills. The quantification method utilized for each pool is listed in Table 2.

**Table 2: Carbon Pools and Quantification Methods**

| Description | Quantification Method |
|---|---|
| Standing Live Carbon (carbon in all portions of living trees) | Measured through forest inventory and Modeled with Forest Vegetation Simulator (FVS) and harvest scheduling models |
| Standing Dead Carbon (carbon in all portions of standing dead trees) | Measured through forest inventory and modeled with Forest Vegetation Simulator (FVS) and harvest scheduling models |
| Forest product carbon in use | Measured through harvest receipts, modeled with Forest Vegetation Simulator (FVS), and calculated using regional Appendix F mill efficiency, decay rate, and landfill values |
| Forest product carbon in landfills | Measured through harvest receipts, modeled with Forest Vegetation Simulator (FVS), and calculated using regional Appendix F mill efficiency, decay rate, and landfill values |

## 2.4 Modeling Management Scenarios

We modeled carbon sequestration volumes in the Elliott State Forest by extrapolating management prescriptions from the structural requirements of the HCPs, meeting the harvest volumes defined as target levels, and examining these activities in the context of the Elliott State Forest landscape. The combination of management prescriptions, annual harvest volumes, and spatial and temporal projections of associated activities constitutes a “management scenario” that we will evaluate for overall carbon sequestration.

We utilized initial inventory data provided by ODF and projected tree growth through the publicly available growth-and-yield software developed by the U.S. Forest Service, the Forest Vegetation Simulator (FVS). We combined this modeling work with a detailed geographic information system (GIS) to develop analyses that reflect on-the-ground conditions and practices.

The four main steps in this process were:

1) Formatting inventory data;
2) Extrapolating silvicultural prescriptions;
3) Defining landscape management actions; and
4) Scheduling harvests.

### 2.4.1 Formatting Inventory Data

We reformatted the Elliott State Forest 2008 inventory data to FVS-compliant file formats using Microsoft Access database queries. This process resulted in two sets of tables, the formatted “treelist” tables, which contain tree-level information, and the stand list tables, which contain stand-level information, histories, and geographic attributes. After creating these input files, we linked the stand level tables to spatial data showing stand and plot locations in order to calculate slope, aspect, elevation, and boundaries.

### 2.4.2 Extrapolating Silvicultural Prescriptions

Prior to running FVS, we created a series of modeling prescriptions based on structural and riparian requirements of the HCPs. These prescriptions accounted for management activities described in the HCPs and were reviewed with Coos District ODF staff.

We classified the Elliott State Forest into management polygons according to three criteria defined in the HCPs: conservation status, proximity to rivers, and age class.

Conservation status is defined by two broad management areas:

- *Conservation zones*—includes both 1) threatened and endangered species core areas, and 2) existing steep, unique, or visual lands
- *Matrix zones*—includes all areas outside conservation zones

Proximity to rivers is defined by riparian zones:

- *Core Riparian Zone*—a buffer extending 25 feet from the stream edge
- *Inner Riparian Management Zone*—a secondary buffer, extending between 25 and 100 feet beyond the stream
- *Outer Riparian Management Zone*—a tertiary buffer, extending from 100 to 160 feet beyond the stream

Given the Elliot’s bimodal age class distribution, we divided the Elliott into two major age categories:

- *Young*—stands less than 65 years of age
- *Mature*—stands greater than 65 years of age

Tables 3 and 4 describe management activities by riparian zones and age classes for conservation and matrix zones, respectively.

**Table 3: Conservation Zone Prescriptions**

| **Riparian Zone** | **Management Activity** |
|---|---|
| Core Zones | No activity |
| Inner and Outer Zones | No activity or forest thinning, intended to develop advanced age structure |
| **Age Class** | **Management Activity** |
| Young | Thinnings at 30 years of age, subject to harvest shifts in five-year increments |
| Mature | Thinnings at 120 years, subject to harvest shifts in five-year increments that may delay thinnings until stands are more than 200 years of age |

**Table 4: Matrix Zone Prescriptions**

| **Riparian Zone** | **Management Activity** |
|---|---|
| Core Zones | No activity |
| Inner zones of small and large fish-bearing streams and large non-fish-bearing streams | • No activity or thinning, intended to develop advanced structure<br>• Thinnings at 30 years for young stands and 120 years for mature stands, subject to harvest shifts |
| Inner zones of small non-fish-bearing streams and outer zones of fish-bearing streams | • For young stands, thinning at 30 years and harvest at 60 years, subject to harvest shifts<br>• For mature stands, thinning at 120 years and harvest at 160 years, subject to harvest shifts<br>• Twenty-five trees/acre (greater than 11" DBH) retained after regeneration harvest |
| Outer zones of large non-fish-bearing streams | • For young stands, thinning at 30 years and harvest at 60 years, subject to harvest shifts<br>• For mature stands, thinning at 120 years and harvest at 160 years, subject to harvest shifts<br>• Ten trees/acre retained after regeneration harvest |
| Outer zones of small non-fish-bearing streams | Same as non-riparian matrix prescriptions for young and mature stands |

| Age Class | Management Activity |
|---|---|
| Young Stands (<65 years) | • One or more commercial thinning<br>• Regeneration harvest that retains three trees/acre; prescriptions may include:<br>  o Harvest at 40 years with no commercial thinning<br>  o Commercial thinning at 30 years followed by harvest at 60 years<br>  o Commercial thinnings at 30 and 50 years followed by harvest at 80 years<br>  o Commercial thinnings at 30, 50, and 80 years followed by harvest at 120 years |
| Mature Stands (>65 years) | • Regeneration harvest that retains three trees/acre (> 11" DBH for ages between 40 and 55 years and > 26" DBH for ages greater than 60 years)<br>• Prescriptions may include:<br>  o Harvest between 120 and 155 years with no commercial thinning<br>  o Harvest between 160 and 200 years after a commercial thinning at 120 years |

In addition to the management prescriptions for conservation and matrix zones, we created a set of general management guidelines that we followed throughout the Elliott. These are described in Table 5.

**Table 5: General Management Guidelines**

| | |
|---|---|
| Pre-Commercial Thinning | • Used with harvests of 40 to 55 years<br>• Implemented between 15-20 years<br>• Reduced stand density to 280 trees/acre |
| Commercial Thinning | • Initiated when the stand density index (SDI) exceeds 55 percent of the maximum for forest type<br>• Made from below<br>• Reduced the SDI to 30 percent of the maximum for initial thinning and 35 percent for later thinnings<br>• Not modeled for species retention |
| Regeneration | • Modeled replanting of 400 trees/acre with the following species mix:<br>o 67.5 percent Douglas fir<br>o 19 percent western hemlock<br>o 10 percent western red cedar<br>o 2.5 percent red alder<br>o 1 percent bigleaf maple<br>• Modeled natural regeneration at 90 trees/acre including minor conifer species and further hardwood individuals<br>• Modeled advanced regeneration of saplings after commercial thinning at 40 trees/acre with a greater proportion of shade-tolerant species |

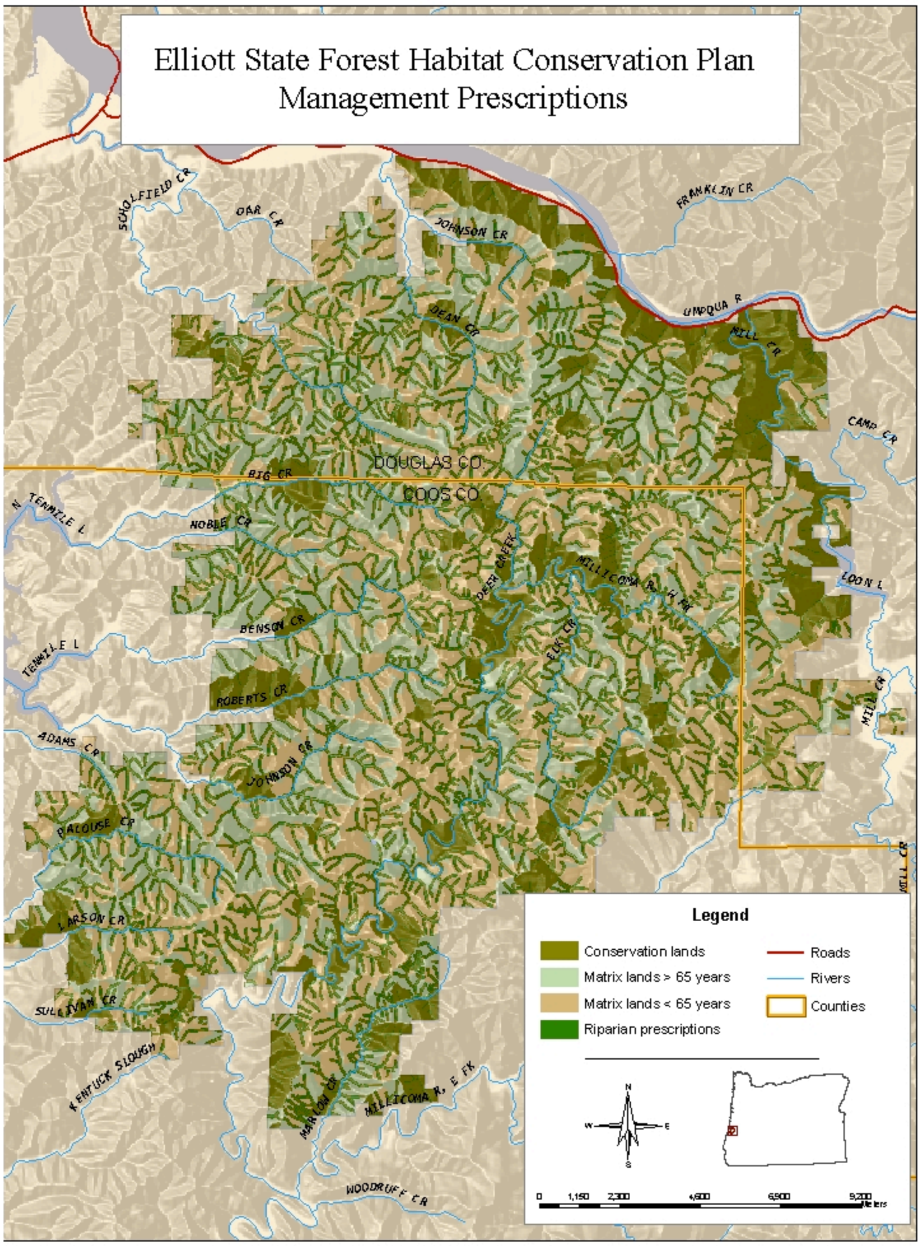
To model a minimum storage scenario, we utilized prescriptions that reflect the Oregon Forest Practices Act, as well as any restrictions that would be associated with the Endangered Species Act on private lands. We followed a conservation area/matrix dichotomy of management classes. However, there was no advanced age structure target for the matrix area and regeneration harvests were allowed in the conservation areas as long as a 50-percent advanced-age-structure target was maintained in the conservation areas. Prescriptions were characterized by:

- Regeneration harvest at 40 years within younger stands
- Regeneration harvest at 120 years within mature stands
- Pre-commercial thinnings, but not commercial thinnings
- Riparian zones modeled according to buffer widths in the Oregon Forest Practices Act and treating Riparian Management Areas as maximum carbon storage or “no harvest” areas

### 2.4.3 Modeling Landscape Management Actions

To simulate the implementation of FVS-modeled prescriptions in the Elliott State Forest landscape, we used stand maps provided to us as part of the overall forest inventory data. These stands were defined as part of the forest inventory and averaged 80 acres in size. When individual forest stands crossed management zones, such as riparian management areas, we subdivided them, creating new management regions as demonstrated in Figure 10. We then assigned a prescription to each of these areas, and imputed the FVS model output accordingly before running the full FVS modeling of the forest.

**Figure 10: Elliott State Forest HCP Management Prescriptions**



### 2.4.4 Scheduling Harvests

We used a scheduling model to project harvesting in a way that simulates actual on-the-ground activity. Without a scheduling model, projections tend to assume overharvesting in the early periods because of homogenous age patterns on the landscape. Harvest scheduling smoothes activity across multiple periods, based on harvest volume targets, while accounting for other management objectives outlined in the HCP. We have modified a model originally developed by Dr. John Sessions of Oregon State University to create our harvest scheduling tool.

Traditional methods of harvest scheduling include both linear programming and heuristic models. Linear programming and its derivatives are not as well suited for handling spatial constraints such as patch size and contiguity, whereas heuristic programming techniques have shown promise in these areas. Heuristics are used to rapidly derive a solution that is assumed to be close to the best possible answer, the so-called optimal solution.

We use a heuristic model based on a simulated annealing algorithm to identify a near-optimal solution for even harvest flows, subject to the age and structure constraints identified in the HCP. This technique for solving combinatorial problems has been used in numerous instances of forest management analysis, as well as in other industries.[21]

The scheduling model attempts to minimize an objective function by choosing a random set of harvest shifts and iterating through different shift combinations until decreases in the objective function are no longer significant. Results are expressed as a single harvest shift that is applied to each actively managed stand. Because of the random nature of the simulated annealing process, a new set of harvest shifts will be identified with each run of the harvest scheduler.

Harvest shifts are variations on a prescription in which the timing of key prescription activities is shifted by a certain number of years, e.g., a 40-year rotation harvest could be “shifted” 5 years, making it a 45-year rotation harvest. No other changes to the prescription are made other than the timing of the key activity.

We used the scheduling optimization model to attain the following goals: 1) the presence of advanced-structure forests over 50 percent of the Elliot State Forest’s area; and 2) a smooth, even harvest target over time. We used the criteria for advanced-age structure defined in Conservation Measure 5.2 of the HCP.[22]

1) 20 trees/acre of > 18" DBH and 100’’ in height
2) 10 trees/acre > 24" DBH
3) 8 trees/acre > 32" DBH

[21] Lockwood, C. and Moore, T. 1993. Harvest scheduling with spatial constraints: a simulated annealing approach. Canadian Journal of Forest Research 23: 468–478. Murray, A. T. and Church, R. L. 1995. Measuring the efficacy of adjacency constraint structure in forest planning models. Canadian Journal of Forest Research 25: 1416–1424. Van Deusen, P. C. 1999. Multiple solution harvest scheduling. Silva Fennica 33: 207–216. Sessions, J., Johnson, D., Ross, J., and Sharer, B. 2000. The Blodgett plan: an active management approach to developing mature forest habitat. Journal of Forestry 98: 29–33.

[22] Oregon Department of Forestry. 2008. Draft Elliott State Forest Habitat Conservation Plan. p. 5-2.

After scheduling the harvests, the model output provides spatially explicit data on harvest volumes, carbon storage, and forest growth across the landscape and over time. By modeling every prescription and potential shift across every stand, we generated a comprehensive dataset describing all possible outcomes according to the modeled prescriptions.

## 2.5 Calculating Carbon Storage

The outputs of this modeling and spatial analysis exercise are a series of files that summarize total carbon in all required carbon pools associated with the starting inventory, harvested wood volumes in cubic feet, and average carbon tonnage in the five scenarios. We used these numbers in a Microsoft Excel spread sheet model to calculate the total carbon sequestered in five-year time periods based on inventory methodologies created by CAR. All totals are presented in metric tonnes of carbon dioxide equivalent (tCO2e).

### 2.5.1 Primary Effects

The outputs of the FVS modeling and harvest scheduling runs provide the total carbon values stored in the carbon pools described earlier. These pools are calculated through species-specific growth and allometric equations, and reflect the remaining above- and below-ground standing forest biomass after harvests.

However, the carbon stored in the forest does not represent the only type of stored carbon that needs to be calculated. Harvested wood continues to store carbon long after it is removed from the site. The length of time this carbon remains stored depends upon the specific wood product created. In addition to wood products that continue to be in use, wood products that are disposed of in landfills effectively store their carbon for the long term.

To reflect the carbon storage in specific categories of wood products and landfills, the CAR Forest Protocol relies on section 1605 (b) of the Energy Policy Act of 1992. This document calculated regional averages for such factors as percentage of different wood products produced in mills, the efficiency of mills in turning raw lumber into processed products, and the long-term percentage of harvested wood products that remains stored in a given year after harvest.

Specific calculations are made by following these steps:

1) Output from the growth and yield modeling are reported in cubic foot units by species.
2) Cubic foot totals for each harvest period are converted into total carbon by multiplying by a dry wood density factor by species to arrive at total pounds of carbon.
3) Total pounds of carbon are converted to metric tonnes of carbon dioxide equivalent.
4) Total metric tonnes of carbon are converted to stored carbon by taking the average of specific product categories that will remain stored for one hundred years.

In CAR, wood product pools are calculated by determining the ratio of different wood products and how fast each of these wood products pools decays. Harvested wood product decay rates for categories of wood products are averaged over 100 years to create a single value that is applied to harvest wood carbon volumes.

### 2.5.2 Secondary Effects

Secondary effects refer to additional greenhouse gas emissions that may occur outside the project site as a result of management activities on the site. In CAR and other protocols, these effects are defined as “leakage.” Leakage calculations attempt to take into account the fact that any reduction in harvested wood on one site will likely be harvested on another forest somewhere in the nearby region. If a reduction in harvest is merely harvested on another site the net effect on the climate will be zero, so a percentage of reduced harvests must be deducted from additional carbon calculated. In our analysis of carbon storage for the Elliott State Forest, we did not consider the effects of leakage, as this analysis was not being completed to assess additional carbon that would delivered in a voluntary carbon offset project.

# 3. Results

Our modeling outputs provide a long-term look, in five-year increments, at scenarios for forest growth, timber yield, and carbon storage under varying management plans. With these data, we compared the three proposed harvest volumes—30, 35, and 40 million board feet/year (MMBF)—and the two boundary scenarios—the maximum and minimum carbon storage potential of the Elliott and its wood products. For this analysis, all carbon volumes were measured in terms of metric tonnes of CO2-equivalent (tCO2e).

We extrapolated the starting forest carbon inventory of 24,500,450 tCO2e in 2010 from data provided by ODF. These data reflect 2008 inventory data projected forward to the current year, so that each scenario is starting from a common point. While this projection does not capture detailed harvest information for the last two years, it limits the complexity and time of modeling, while ensuring a common starting point for our analysis.

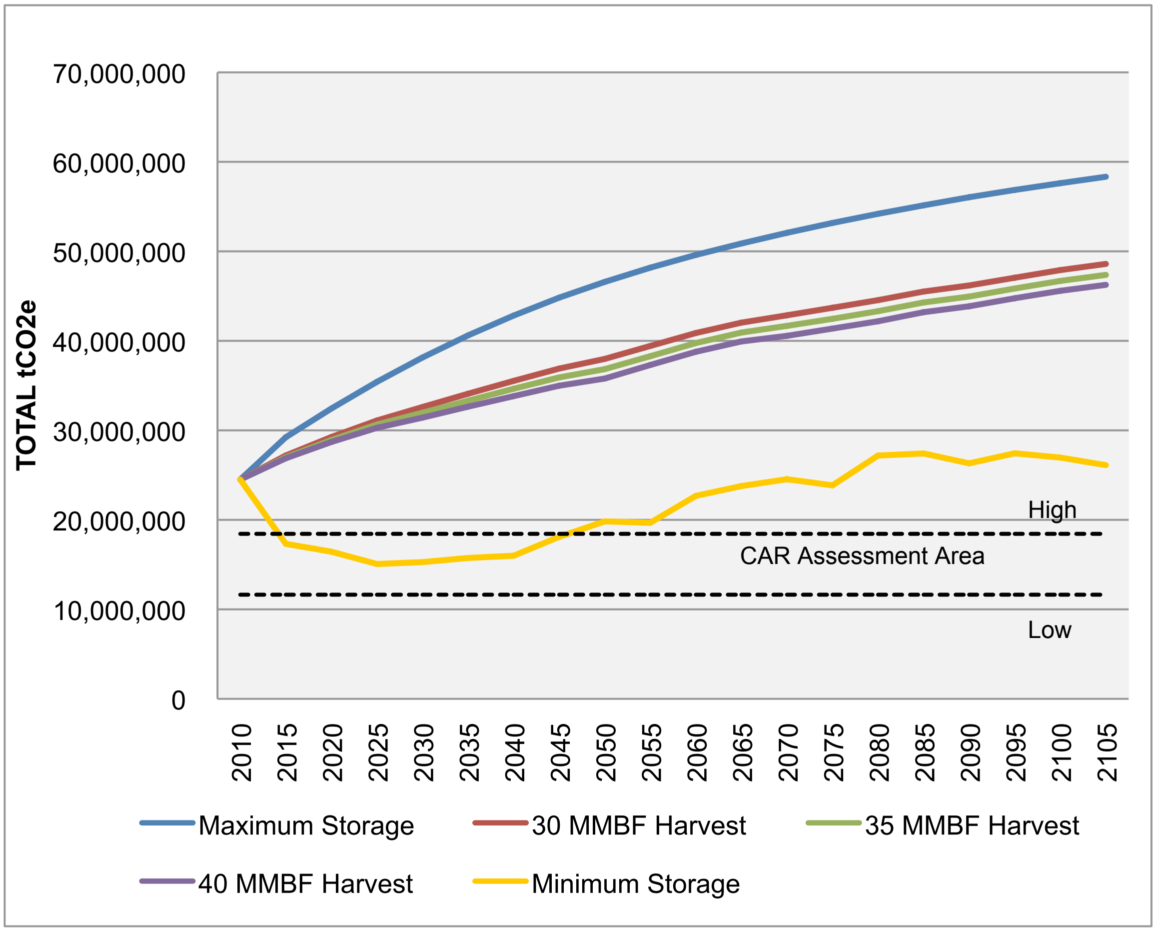
Each scenario tracks additional carbon storage in five-year increments from spatially specific forest growth across the Elliott State Forest. The maximum storage scenario assumes that management consists of no harvest or thinnings. The minimum storage scenario assumes timber harvest according to Oregon Forest Practices Act and Endangered Species Act regulations. The three harvest volume targets assume management prescriptions that meet the forest structure requirements of the HCP. All scenarios follow the Climate Action Reserve protocol in accounting for carbon stored in in-use and discarded wood products.

Cumulative differences are striking for what they say about the potential of Pacific Northwest forests to store carbon. If no harvests were to occur in the Elliott State Forest, the total amount of carbon stored would be approximately 46.6 million metric tonnes of carbon dioxide equivalent (MMtCO2e) by 2050, approximately 68.5 percent of the annual emissions of greenhouse gases for the entire state in 2007 (68 MMtCO2e).[23]

The potential differences that alternative management could achieve are demonstrated in Figure 11. This set of graphs shows how much carbon would be stored by four management alternatives (no harvest, 30 MMBF, 35 MMBF, 40 MMBF) compared with what would be allowed on the site if it was in private hands. The difference in carbon storage between the maximum and minimum values is 20 million metric tonnes of carbon dioxide equivalent (MMtCO2e) in 2025. This number increases to a total of approximately 27 MMtCO2e additional metric tonnes by 2050. To put this amount in context, 27 MMtCO2e represents approximately 39 percent of the total greenhouse gas emissions for the state of Oregon in 2007 (68.5 MMtCO2e).

[23] Revision and Update to Oregon Greenhouse Gas Inventory. Oregon Department of Energy (http://www.oregon.gov/ENERGY/GBLWRM/Oregon_Gross_GhG_Inventory_1990-2005.htm)

**Figure 11: Carbon Storage Potential**




The HCP-based management scenarios we modeled in this report fall somewhere between the maximum and minimum storage possible on the site. In percentage terms, it can be seen that the three HCP and harvest level scenarios would store between 60 and 68 percent of the maximum possible on the site by 2050 (Figure 12).

**Figure 12: Cumulative Carbon Storage Above Minimum Storage Scenario**

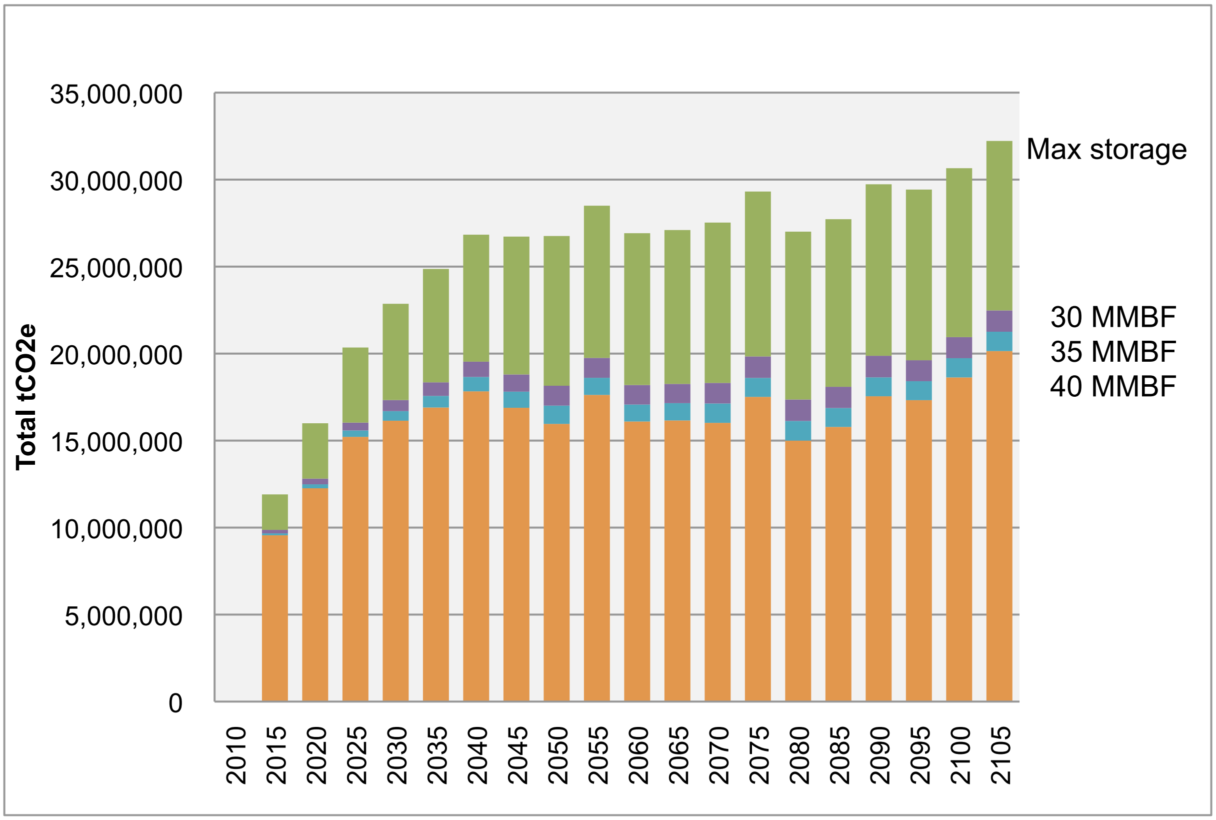
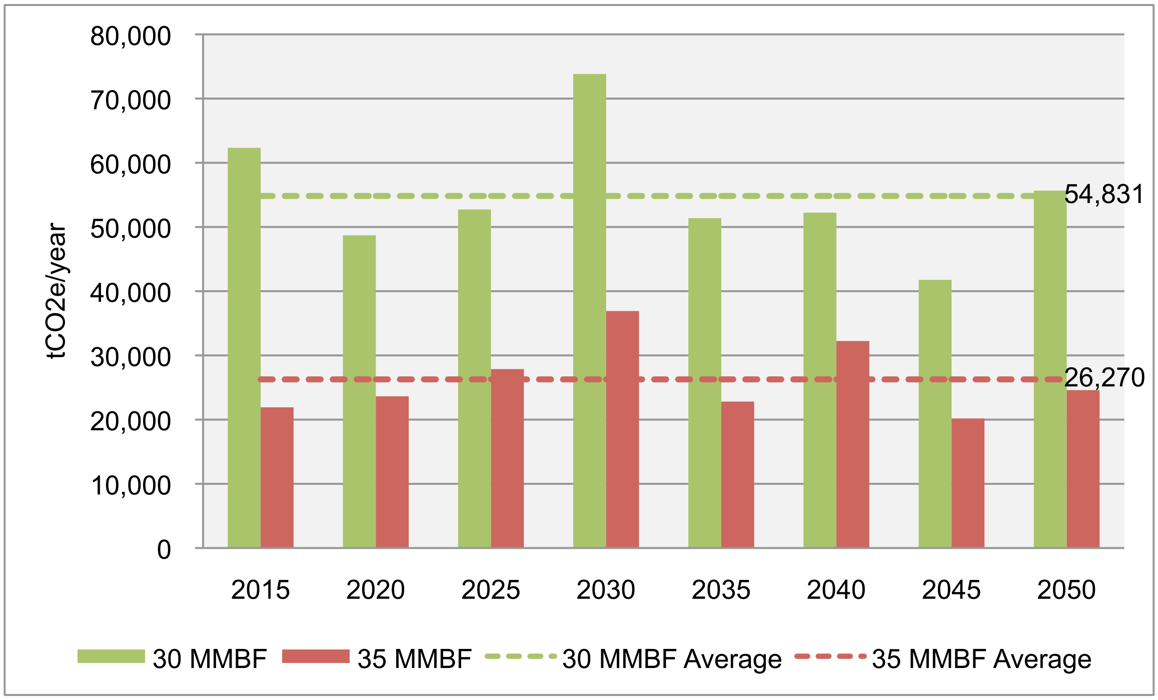


Figure 13 shows annual differences between the three proposed harvest levels. We take the highest harvest level as a baseline and compare the other harvest levels against it. When evaluated annually, switching management from the 40 MMBF harvest scenario to the 30 MMBF will save the equivalent amount of greenhouse gases as removing approximately 10,000 cars from United States' highways for a year.

**Figure 13: Annual average reductions with different harvest scenarios**



# 4. Discussion

Our results indicate that forest management has the potential to contribute significantly to Oregon's greenhouse gas emissions reductions. Forest management practices that, for example, extend riparian buffers, follow longer rotation cycles, and limit harvests on steep and unstable slopes and in areas of high conservation value store a great deal more carbon than what can be achieved by more intensive forest management that maximizes timber harvest. Our modeling has demonstrated that the difference between a "grow only" (no harvest) scenario and an ecological forest management scenario is less than might be expected. Thus, forests in our region can store a significant amount of carbon while continuing to supply a steady and reliable stream of timber.

The potential of the site given in Figure 11 demonstrates that there is a great deal of carbon that could be stored across the Elliott State Forest if alternative management possibilities were considered. We estimate that potential carbon storage could reach 20 million metric tonnes of carbon dioxide equivalent (MMtCO2e) by 2025 and 27 MMtCO2e by 2050 if the maximum storage scenario was adopted on the site.

Among the HCPs proposed for the Elliott State Forest, each of which is designed to protect habitat for threatened species, we estimate the differences in management between the 30 and 40 MMBF harvest levels equates to a difference of approximately 50,000 tCO2e per year on average over the next 40 years. While this difference may appear small in relation to the total stored carbon on the site, this is equal to the annual carbon emissions of about 10,000 cars traveling on U.S. highways.

Numerous complications affect our selection of a baseline for this analysis. In a market context, CAR would require a baseline determined by regional management practices, and management in the industrial forestlands of Oregon may provide for carbon sequestration close to our minimum storage scenario. Another approach to setting a baseline would be to look at historical management in the Elliott. Against average timber harvest levels in the Elliott, which averaged 23.7 MMBF annually from 1995 through 2010, none of the proposed timber harvest levels under the HCP would offer additional carbon storage.

One scenario we did not evaluate was the comparison of the different management scenarios against the CAR protocol baseline for public lands. The CAR protocol requires an analysis of historical management trends and a review of how current and future public policy will affect carbon stocks. While this analysis was possible given our methods, we did not follow this approach because our goal was to evaluate potential management decisions rather than to verify a tradable market commodity. Thus, the development of alternative management scenarios was outside the scope of our analysis.

As stated in ODF planning documents, the primary management goal in the Elliott State Forest is difficult to achieve:

1) *Actively manage CSFLs with the objective of obtaining the greatest benefit for the people of this state, consistent with the conservation of this resource under sound techniques of land management to maximize revenue for the CSF over the long term*

As our analysis demonstrates, there is a tradeoff between maximizing revenue for the common school fund and sequestering additional greenhouse gases through active management. Increasing carbon storage in the Elliott State Forest involves reducing harvests in the short term; therefore, increasing carbon storage will reduce revenue for the common school fund. However, we also found that a lower level of harvest in the short term could eventually lead to a higher level of sustainable annual growth. This approach may also be consistent with the state's long-term fiduciary responsibilities, as well as maintain higher levels of carbon storage capacity on the landscape.

The significant impacts of climate change on our forests and their continued management requires that we evaluate the potential of our forests to store more carbon and include this in the potential outcomes of the state's management plans. The relative tradeoffs and policy choices of carbon storage will be a factor the State Land Board will continue to be faced with in future decisions on the management of Common School Forestlands in the Elliott State Forest.

# 5. References

Climate Action Reserve. Current Forest Project Protocol (http://www.climateactionreserve.org/how/protocols/adopted/forest/current/)

Draft Roadmap. Forest Working Group Recommendations to the Global Warming Commission, September 2010.

Environmental Protection Agency. 2005. Emission Facts: Greenhouse Gas Emissions from a Typical Passenger Vehicle. EPA420-F-05-004 (http://www.epa.gov/oms/climate/420f05004.htm)

Governor's Advisory Group for Global Warming. 2004. Oregon Strategy for Greenhouse Gas Reductions.

Governor's Climate Change Integration Group. 2008. Final Report to the Governor: A Framework for Addressing Rapid Climate Change.

IPCC. 2007. Summary for Policymakers. In: Climate Change 2007: Mitigation. Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [B. Metz, O.R. Davidson, P.R. Bosch, R. Dave, L.A. Meyer (eds)], Cambridge University Press, Cambridge, UK and New York, USA.

Lockwood, C. and Moore, T. 1993. Harvest scheduling with spatial constraints: a simulated annealing approach. Canadian Journal of Forest Research 23: 468–478.

Murray, A. T. and Church, R. L. 1995. Measuring the efficacy of adjacency constraint structure in forest planning models. Canadian Journal of Forest Research 25: 1416–1424.

Oregon Department of Energy. Revision and Update to the Oregon Greenhouse Gas Inventory. (http://www.oregon.gov/ENERGY/GBLWRM/Oregon_Gross_GhG_Inventory_1990-2007.htm)

Oregon Department of Forestry. 2006. Elliott State Forest Management Plan.

Oregon Department of Forestry. 2008. Common School Forest Lands Annual Report FY2008. (http://www.oregon.gov/ODF/STATE_FORESTS/docs/management/annual_reports/2008_CSFL_Report_for_web.pdf)

Oregon Department of Forestry. 2008. Draft Elliott State Forest Habitat Conservation Plan. (http://www.oregon.gov/ODF/STATE_FORESTS/elliott.shtml#Habitat_Conservation_Plan_)

Oregon Department of Forestry. 2009. 2009-2011 Backgrounder on the Elliott State Forest. (http://www.oregon.gov/ODF/docs/2009_Backgrounder_Elliott_State_Forest.pdf)

Oregon Global Warming Commission. 2010. Interim Roadmap to 2020. (http://www.keeporegoncool.org/content/roadmap-2020)

Sessions, J., Johnson, D., Ross, J., and Sharer, B. 2000. The Blodgett plan: an active management approach to developing mature forest habitat. Journal of Forestry 98: 29–33.

Van Deusen, P. C. 1999. Multiple solution harvest scheduling. Silva Fennica 33: 207–216.